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ALPHA-PARTICLE ACTIVITY ASSOCIATED WITH LONG-LIVED RADIOACTIVE DUST SAMPLES FROM AN UNDERGROUND URANIUM MINE

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MICROMEDIA

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ALPHA-PARTICLE ACTIVITY ASSOCIATED WITH LONG-LIVED RADIOACTIVE DUST SAMPLES FROM AN UNDERGROUND URANIUM MINE

J. Bigu*

ABSTRACT

The α-particle activity associated with Long-Lived Radioactive Dust (LLRD) samples from an underground uranium mine has been measured. The α-particle activity measured on mine air samples has been related to the amount of silica dust collected on the samples, determined by X-ray diffraction analysis. The long-lived α-particle activity was plotted against silica dust content in the samples. A linear relationship with low correlation coefficient was found which can be expressed by the equation $A = mW_Q + b$, where A and W_Q represent the α-particle activity (mBq) and silica dust mass (mg) in the sample, respectively. Because measurements of LLRD are time-consuming and expensive, the study was aimed at obtaining a useful relationship between the two variables to enable calculation of LLRD α-particle activity from silica dust measurements, the latter conducted on a routine basis by our laboratory for the mine under consideration. Recommendations for further studies are indicated.

Key words: Long-lived radioactive dust; Uranium mines; Underground.

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ACTIVITÉ DES PARTICULES ALPHA ASSOCIÉE A DES ÉCHANTILLONS DE POUSSIERE RADIOACTIVE DE LONGUE PÉRIODE PROVENANT D'UNE MINE D'URANIUM SOUTERRAINE

J. Bigu*

RÉSUMÉ

L'activité des particules α associée à des échantillons de poussière radioactive de longue période (PRLP) provenant d'une mine d'uranium souterraine a été mesurée. Une relation a été établie entre l'activité des particules α mesurée dans des échantillons d'air de mine et la quantité de poussière de silice recueillie dans les échantillons, déterminée à l'aide de l'analyse par diffraction des rayons X. On a représenté graphiquement l'activité des particules α de longue période en fonction de la teneur en poussière de silice des échantillons. On a obtenu une relation linéaire avec un faible coefficient de corrélation qui peut être exprimée par l'équation $A = mW_Q + b$, où a et W_Q représentent respectivement l'activité des particules α (mBq) et la masse de poussière de silice (mg) dans l'échantillon. Comme les mesures portant sur la PRLP demandent beaucoup de temps et sont coûteuses, l'étude visait à fournir une relation utile entre les deux variables afin de permettre le calcul de l'activité des particules α de PRLP à partir des mesures portant sur la poussière de silice, ces dernières étant effectuées de façon régulière par notre laboratoire pour la mine à l'étude. Les recommandations concernant des études plus poussées sont indiquées.

Mots-clés : poussière radioactive de longue période; mines d'uranium; souterraine.

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INTRODUCTION

In underground uranium mines and uranium mills, dust emissions contain certain radionuclides. These radionuclides have been identified by a variety of methods, such as α- and γ-spectroscopy, neutron activation analysis, particle induced X-ray emission, fluorescence, and spectrophotometry (1-4). The radionuclides identified include the parents of the natural uranium and thorium decay chains (^{235}U, ^{238}U, and ^{232}Th), and their short-lived and long-lived decay products. Dust that contains long-lived radionuclides is commonly referred to as Long-Lived Radioactive Dust (LLRD).

The inhalation of dust generated in mining and milling operations poses a potential health hazard, and if the dust contains long-lived radionuclides, inhalation can pose an even greater occupational health hazard. Because of the health risks associated with the inhalation of LLRD, its accurate characterization and quantification is of great practical importance in order to calculate personal occupational exposures.

Because radionuclides are contained in uranium (U) ores, and hence in dust particles produced in the course of unit mining and milling operations, the hypothesis was advanced that there might be a relationship between dust collected on filters and the radioactivity associated with the dust (5). This suspicion was partly confirmed when radioactivity (α-particle) measurements were carried out on a number of air samples (taken from underground uranium mines and uranium mills at a specific geographical location) on which total dust and silica dust mass measurements had previously been made as part of a routine program conducted by the Elliot Lake Laboratory for some mining companies. The air samples measured and analyzed in this study corresponded to samples collected during the period 1983-85.

This report presents data on a continuation of the above program, namely, the measurement and analysis of samples collected during the period 1987 to the beginning of 1989.

THEORETICAL BACKGROUND

The uranium deposits corresponding to the mines where dust samples were taken consist of layers and channels of Precambrian, pyrite-rich, quartz-pebble conglomerate. The minerals within the conglomerates mainly consist of pyrite, brannerite (uranium titanate) and uraninite (uranium oxide) which are associated with varying amounts of uranothorianite (silicate of uranium and thorium), among other minerals. The U and Th minerals are associated mainly with sulphides, e.g., pyrites. The minerals occur interstially to the quartz pebbles in the conglomerate matrix.

A quantitative study on the relationship between dust and the radioactivity associated with it is by no means trivial or straightforward. In such studies the following should be given careful consideration:

1. α-particle selfabsorption effects, i.e., α-particle energy degradation and α-particle absorption in the dust layer deposited on the filter during air sampling;
2. Characteristics of the dust deposited on the filter, e.g., chemical composition, size distribution, and electrical charge; and
3. Type of dust sampling device, e.g., particle size threshold, cut-off size and other parameters.

Item 1 depends, in turn, on the following:

a) α-particle energy, i.e., radioisotope under consideration;
b) spatial distribution of dust deposition on the filter;
c) thickness of the dust layer;
d) dust size distribution;
e) chemical composition of the dust, i.e., atomic number of the different constituents if more than one.

Item 2 is a function of the following items:

a) mining and milling operations such as crushing, blasting, drilling, slushing, mucking, transportation, leaching, etc.;

b) mining and milling activities such as vehicle traffic, personnel traffic, wetting, etc.;

c) environmental factors such as relative humidity and temperature; and

d) airflow conditions, recirculation paths, air leakages, etc. at the working location.

In the investigation reported here, however, some of the above items have not been considered in detail for lack of pertinent information and/or for the sake of simplicity. For example, data (i.e., samples) were collected using only one type of monitoring instrument (nylon cyclone) and always following the same operational procedure. Furthermore:

a) no direct size distribution data are available because no concurrent measurements of size distribution, with say multistage cascade impactors or particle size optical counters, were conducted; and

b) because of insufficient numbers of samples for statistical confidence, no attempt has been made to separate samples according to different mining operations. Hence, all operations have been lumped together for the purpose of statistical analysis.

The analysis presented here considers two independent sample populations collected, respectively, during January 1987 to June 1988, and October 1988 to January 1989. One important consideration of which the reader should be aware is that because of the long half-life of the radioisotopes measured, the α-particle activity associated with the dust samples is rather low. Hence, the statistical error associated with the radioactivity measurements is in some cases significant.

EXPERIMENTAL PROCEDURE

Dust samples were taken at an underground uranium mine at a variety of mine working locations. Dust samples were collected on silver membrane filters (5 μm mean pore size) using dust samplers of the nylon cyclone type.

Total dust mass and quartz dust mass in the respirable range (<1-10 μm) were estimated. Total dust mass was measured by weighing the filters before and after the samples were collected. Quartz dust was measured by X-ray diffraction analysis (6).

Alpha-particle activity from long-lived radionuclides associated with dust samples was estimated by gross α-count using α-particle counters with a ZnS(Ag) screen optically coupled to a photomultiplier tube, and associated electronic circuitry, as the α-particle detector. Alpha-particle activity measurements were made no earlier than one month after the dust samples were taken. This procedure was followed to ensure, quite conservatively, complete decay of airborne short-lived decay products of radon and thoron collected in the filter during sampling. It should be noted that the short-lived decay products of radon and thoron arise from the decay of a) long-lived radionuclides, such as ^{226}Ra, in dust; and b) radon (^{222}Rn) and thoron (^{220}Rn) in mine air. The short-lived radioactivity from item b) is referred to as airborne activity and, although collected during sampling, is not associated with dust, i.e., item a). Radioisotope identification was carried out by α-spectrometry as discussed elsewhere (1,3,4).

Gross α-particle activity in each sample was measured as follows. Three 45 min α-particle background count measurements were taken daily for each counting instrument, i.e., scalers. Each sample was counted twice sequentially for 45 min each time. The average values for the background and sample α-count, in counts per second (cps), were calculated. The difference in α-count, i.e., net α-count, was computed. The net α-count was converted into absolute disintegration rate, in disintegrations per second (dps), i.e., Becquerels (Bq), where, by definition, 1 Bq = 1 dps.

The airborne α-particle activity concentration, A_s, in Bq/m^3, is given by Equation 1:

$$A_s = 10^3 \, A/QT_s \qquad (1)$$

where, Q is the air sampling flow rate in L/min, and T_s is the sampling time in min. The symbol A is the long-lived α-particle activity measured in Bq in the dust sample. This activity is given by $A = \bar{N}_\alpha/\epsilon$, where $\bar{N}_\alpha$ is the average net α-particle count in cps, and ϵ is the α-particle counting efficiency of the α-particle counter used. The efficiency of the counter was determined using a standard ^{241}Am source of activity traceable to the U.S. National Bureau of Standards.

Alpha-particle counting was conducted using detector/counter arrangements (scalers for brevity) consisting of a 25 mm diameter ZnS(Ag) screen optically coupled to a photomultiplier tube and associated electronic circuitry model Tri-Met 372A, manufactured by Tri-Met Instruments, Winnipeg, Canada.

Two independent sample populations were measured and analyzed, namely, 300 samples collected during the period January 1987 to June 1988, and 214 samples collected during the period October 1988 to January 1989. Only dust samples with total respirable dust mass greater than about 0.03 mg were measured and analyzed for the purpose of the present investigation. This represents over 80% of the total number of samples available, collected underground during the above periods.

The above procedure was followed because:

a) previous data (5) had shown that the α-particle activity associated with the dust collected in the samples was related directly to either the total respirable dust mass or the respirable quartz dust mass fraction, and

b) the grade of the uranium ore in the mine investigated was not particularly high, and hence, the α-particle activity measured on the dust samples was rather low. This is compounded by the relatively high α-particle background of the scalers used because of the constant presence of airborne ^{222}Rn and ^{220}Rn progeny in buildings. (Other contributions to the background include contamination by radioactive dust from sample handling,

cosmic background, and electronic noise.)

The dust mass selection procedure indicated above should not be viewed as introducing an unnecessary and unwanted bias into the measurements. The sole reason for the selection was to improve the statistics of α-particle counting.

Analysis of the two dust sample populations was done by linear regression techniques using the least squares method. The sample populations analyzed here are representative of a variety of mining operations. No dust size distribution measurements were conducted, hence, important parameters such as the Mass Median Aerodynamic Diameter (MMAD) and the Activity Median Aerodynamic Diameter (AMAD) are not known.

EXPERIMENTAL RESULTS AND DISCUSSION

The data obtained for the two sample populations analyzed have been summarized in Figures 1 to 10, and Tables 1 and 2. For simplicity, these two sample populations will be analyzed separately.

A. FIRST SAMPLE POPULATION (JANUARY 1987 TO JUNE 1988)

Data corresponding to this sample population are presented in Figures 1 to 4, and Table 1. Figures 1 and 2 show frequency histograms for the silica dust mass samples, i.e., number of samples within a given dust mass range for two slightly different silica dust mass ranges, namely, 0.02 to 1.3 mg (Figure 1), and 0.04 to 1.6 mg (Figure 2). The maxima of these two distributions are, respectively, ~0.04 mg (Figure 1), and ~0.06 mg (Figure 2).

The values for the quartz dust mass shown in Figures 1 and 2 can easily be converted into airborne silica dust concentration by dividing the values for the quartz dust mass by the total volume of air sampled, $V_T = (QT_s)$, by the instrument, where Q is the air flowrate, and T_s is the sampling time. For a regular working shift T_s = 7.5 - 8.0 h, which for the sampling flowrate commonly used, i.e., Q_T = 1.7 L/min, it represents V_T ~0.8 m^3. The above

quartz dust mass maxima shown in Figures 1 and 2 correspond, therefore, to a concentration of 0.05 mg/m^3 and 0.075 mg/m^3, respectively. (Note: for the sake of brevity, the distribution histograms for LLRD for this particular sample are not shown.)

Figures 3 and 4 show LLRD α-particle activity versus silica dust mass measured in the samples for two size ranges, namely, 0.03 to 1.2 mg (Figure 3), and 0.03 to 0.28 mg (Figure 4). The first size range covers the entire silica dust mass range investigated, whereas the second mass range represents >90% of the total number of samples analyzed. Also shown in Figures 3 and 4 are the best fitted straight lines through the data points.

The relationship (correlation) between LLRD α-particle activity and silica dust mass derived from Figures 3 and 4 by the least squares regression analysis method can be represented by the following expressions:

$$A(mBq) = 132.26\ W_Q + 7.71 \quad ; \quad C.C. = 0.79 \qquad (2)$$

for Figure 3, and

$$A(mBq) = 175.89\ W_Q + 4.66 \quad ; \quad C.C. = 0.51 \qquad (3)$$

for Figure 4.

Where in the above expressions, A stands for the LLRD α-particle activity and W_Q represents the silica dust mass in mg. The symbol C.C. stands for correlation coefficient.

B. SECOND SAMPLE POPULATION (OCTOBER 1988 TO JANUARY 1989)

Data corresponding to the analysis of the second sample population are shown in Figures 5 to 10, and Table 2.

Figure 5 shows the frequency histogram for the quartz dust mass corresponding to the samples examined. As for the first sample population, the maximum corresponding to the distribution is about 0.04 mg, i.e., ~0.05 mg/m^3 assuming a full working shift, i.e., V_T ~0.8 m^3.

Figure 6 shows the frequency histogram for the LLRD α-particle activity corresponding to the sample population analyzed. The graph shows that most of

the samples have an activity in the range 5 to 35 mBq, with a maximum at about 15 mBq.

Figure 7 shows the frequency histogram for the specific LLRD α-particle activity, i.e., α-particle activity per unit mass of silica dust (mBq/mg). One would expect, in principle, that for a given dust size distribution, mining operation, constant or fixed ore grade, and assuming that no α-particle absorption effects in silica dust take place, the frequency distribution should be single-valued or nearly single-valued. The fact that a broad range of values for the LLRD specific activity is obtained is clearly indicative that different dust size distributions, most likely arising from different mining operations, and self-absorption effects, are operative. The result is very important and the true cause(s) should be thoroughly investigated.

Figures 8 to 10 show LLRD α-particle activity versus silica dust mass for three dust mass ranges, namely 0.03 to 0.12 mg (Figure 8), 0.03 to 0.18 mg (Figure 9), and 0.03 to 0.28 mg (Figure 10).

The relationship between LLRD α-particle activity and silica dust mass derived from Figures 8 to 10 by linear regression analysis using the least squares method can be represented by the following expressions:

$$A(mBq) = 168.29\ W_Q + 4.5 \quad ; \quad C.C. = 0.37 \tag{4}$$

for 0.03 to 0.12 mg (Figure 8);

$$A(mBq) = 145.25\ W_Q + 5.6 \quad ; \quad C.C. = 0.41 \tag{5}$$

for 0.03 to 0.18 mg (Figure 9); and

$$A(mBq) = 157.21\ W_Q + 4.8 \quad ; \quad C.C. = 0.46 \tag{6}$$

for 0.03 to 0.28 mg (Figure 10).

Although the relationships described by Equations 4 to 6 do not differ by much (within 20%) from Equations 2 and 3, and other data published elsewhere (5), the correlation coefficients (C.C.) obtained for these studies (Equations 2 to 6) are significantly lower, and rather poor, than that obtained for other previous studies (5). A possible cause for this

discrepancy was indicated above, namely, the use of a different dust sampling device.

FURTHER ANALYSIS OF THE EXPERIMENTAL DATA

The analysis of the data presented in this report suffers from two major weaknesses, namely:

1. the samples have not been separately evaluated, and analyzed according to mining operations; and
2. α-particle self-absorption effects have not been taken into account.

Because different mining operations are generally characterized by significant differences in radioactivity (and dust mass) versus dust size distribution, analysis of samples according to mining operations is of vital importance. Furthermore, the AMAD and MMAD of the LLRD α-particle activity and particle size distributions, respectively, may influence α-particle self-absorption substantially. Unfortunately, data on mining operations and LLRD characterization were not available from the mining company at the time the present analysis was initiated. However, a few observations regarding the data shown in Figures 3 and 4, and Figures 8 to 10 are worth noting:

a) data points with high silica mass content and low α-particle activity are indicative of either one, or more of the following:
   i) low ore grade;
   ii) large dust particles, i.e., large dust size distribution, and hence potentially large α-particle self-absorption effects; and
   iii) silica dust particles devoid or partially 'stripped' of long-lived radionuclides separated in other mass 'aggregates' from silica dust particles in the size reduction process characteristic of the particular mining operation.

   Data points corresponding to item a) appear in the lower right hand portion of the graphs.

b) data points with low silica dust mass content and high α-particle activity are indicative of either one, or more of the following:

i) high ore grade;

ii) small dust particles, and hence, low α-particle self-absorption effects;

iii) separation and purification mining operations such as leaching, and other chemical or physico-chemical operations; and

iv) selective separation of silica dust from long-lived radionuclides in the processes indicated in item iii).

Data points corresponding to item b) appear in the upper left hand portion of the graphs.

It is clear from the above discussion that LLRD characterization (i.e., α-particle activity and particle size distribution) is of paramount importance in order to interpret field data. However, the actual airborne LLRD characterization is not the only item of practical interest, but more importantly, the particle size sampling characteristics of the sampling device, such as cut-off size, etc., play a major role. This is so because different dust sampling devices sampling the same dust atmosphere collect significantly different size distributions or size fractions on the collecting filter.

Finally, with regard to α-particle self-absorption, the following considerations are important in the calculation of self-absorption effects:

1. Spatial distribution of LLRD in the filter. The spatial distribution depends on the sampling device used, e.g., size cut-off, sampling 'head' geometry, sampling flowrate, and other parameters. The LLRD spatial distribution can be studied using scanning techniques such as electron microscopy.

2. Thickness of LLRD on the filter. This parameter is difficult to estimate because of item 1. An average value for the LLRD layer thickness can be calculated from the total LLRD mass and the surface area covered by it.

However, this figure is of limited value because of the inhomogeneous spatial distribution of LLRD on the filter.

CONCLUSIONS AND RECOMMENDATIONS

The main conclusions that can be derived from this study are the following:

1. The relationships found between LLRD and silica dust mass were within ~20% of the values previously obtained in other investigations, except for significantly lower correlation coefficients. It is suspected that this may have to do, at least partly, with a change in the sampling device used to collect the air sample.
2. The relationships obtained in item 1 are not site-specific or mining operation-specific. They are rather of a general nature obtained by lumping together all the available data.

In view of the above, the following items are recommended:

1. Old data and newly collected data should be analyzed according to mining operation.
2. Adoption of a given instrument so that data obtained with this instrument (i.e., sampling device) can be readily compared.
3. Thorough study of the sampling characteristics of the sampling device chosen, or rather adoption of the most suitable instrument available, compatible with physical, practical and economic constraints.
4. Careful study of the errors associated with the measurement of LLRD α-particle activity with regard to self-absorption and other effects.

ACKNOWLEDGEMENTS

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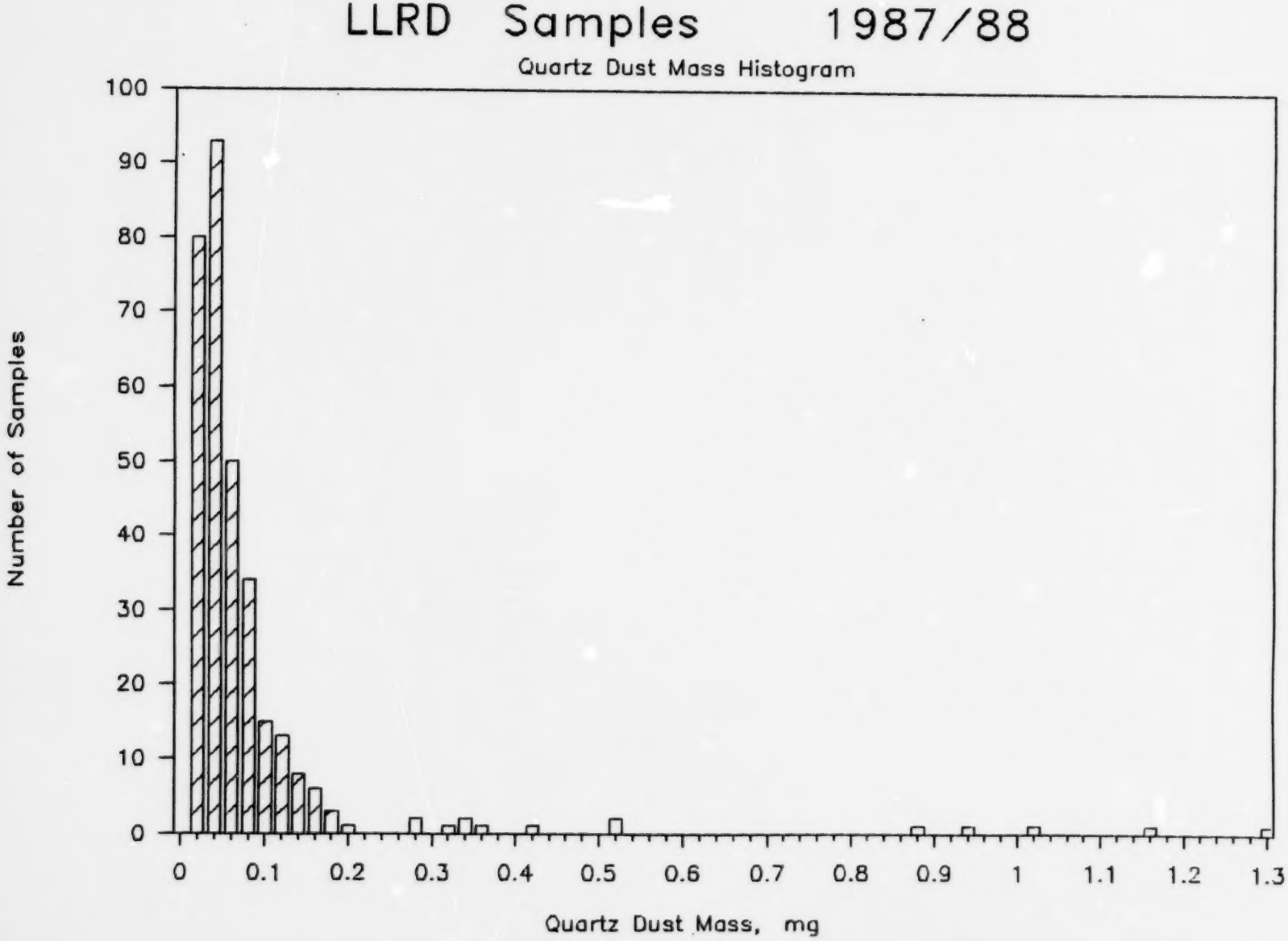

Fig. 1 - Quartz dust mass frequency distribution for first sample population.

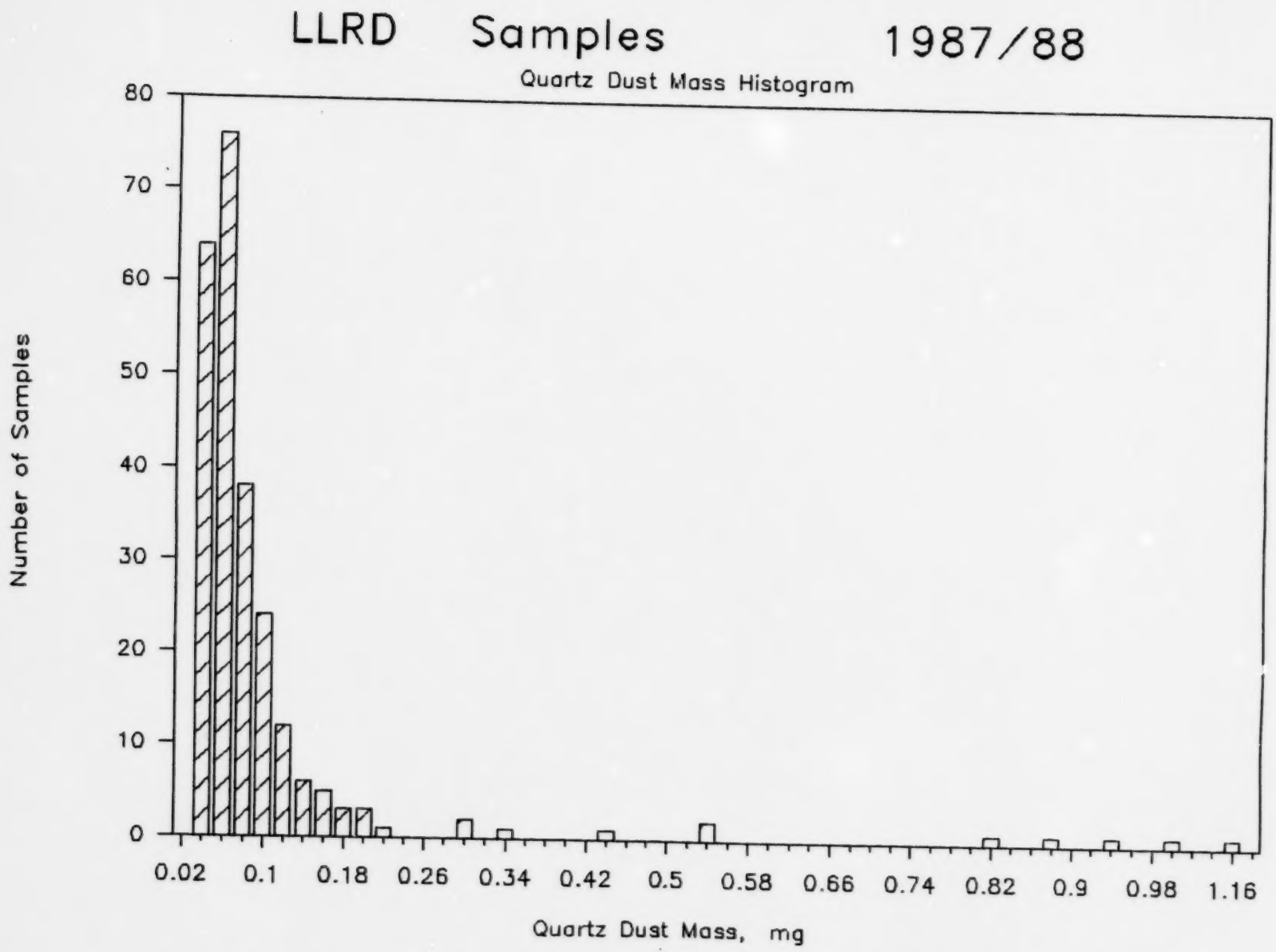

Fig. 2 - Quartz dust mass frequency distribution for first sample population.

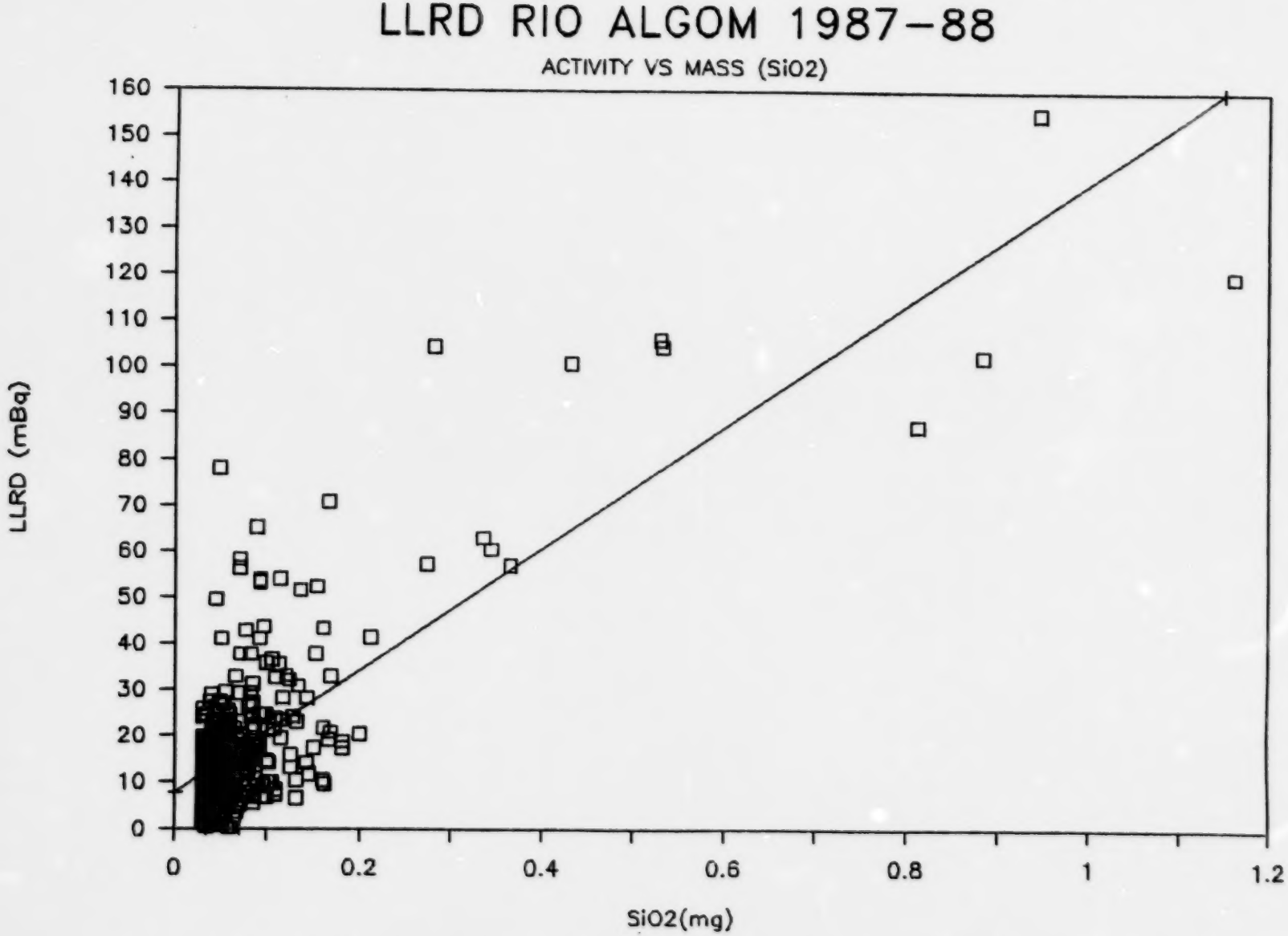

Fig. 3 - Long-Lived Radioactive Dust (LLRD) versus silica dust mass (SiO_2) for the first sample population. Also shown is the best fitted line through the data points.

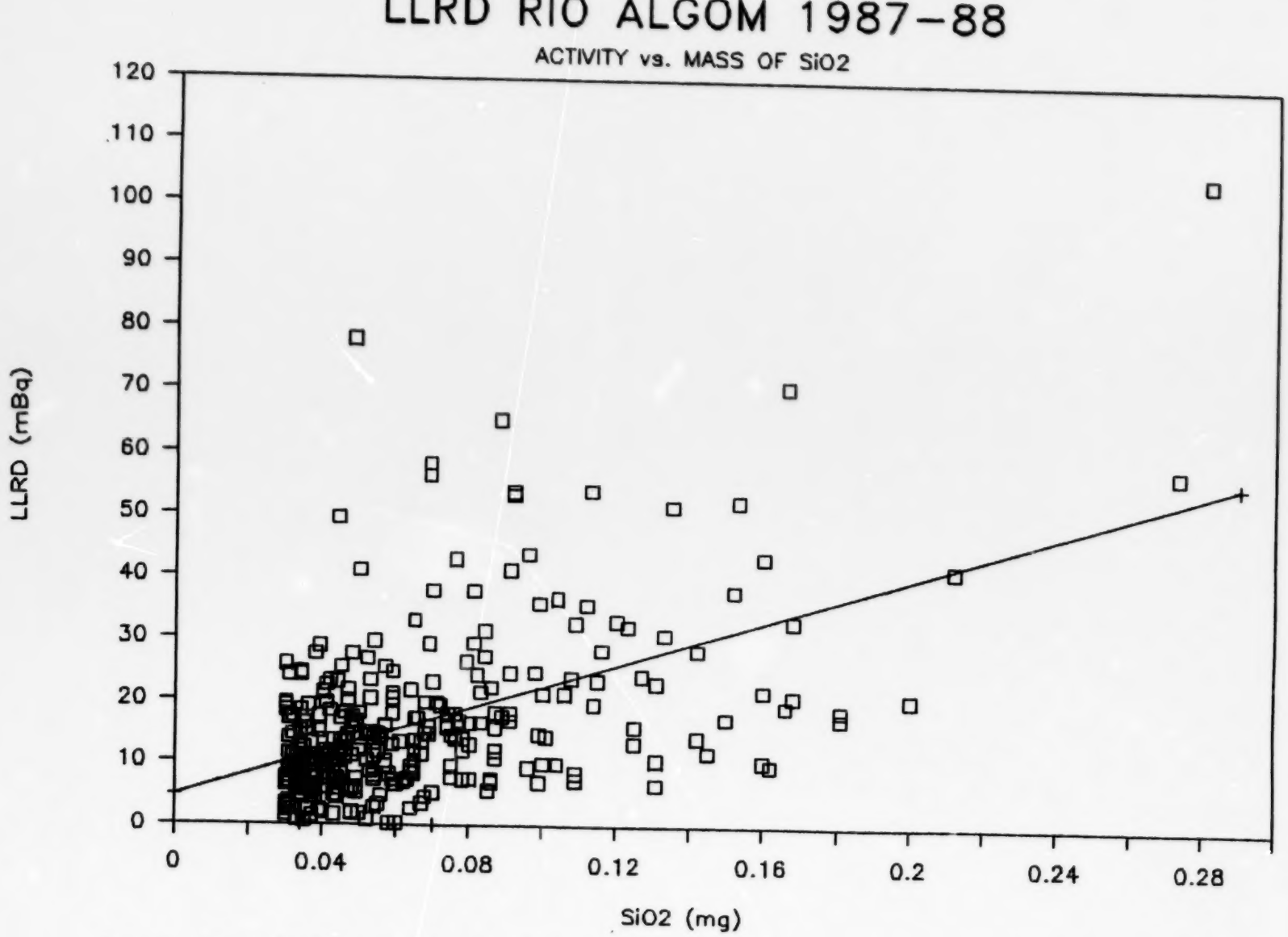

Fig. 4 - Long-Lived Radioactive Dust (LLRD) versus silica dust mass (SiO_2) for the first sample population. Also shown is the best fitted line through the data points.

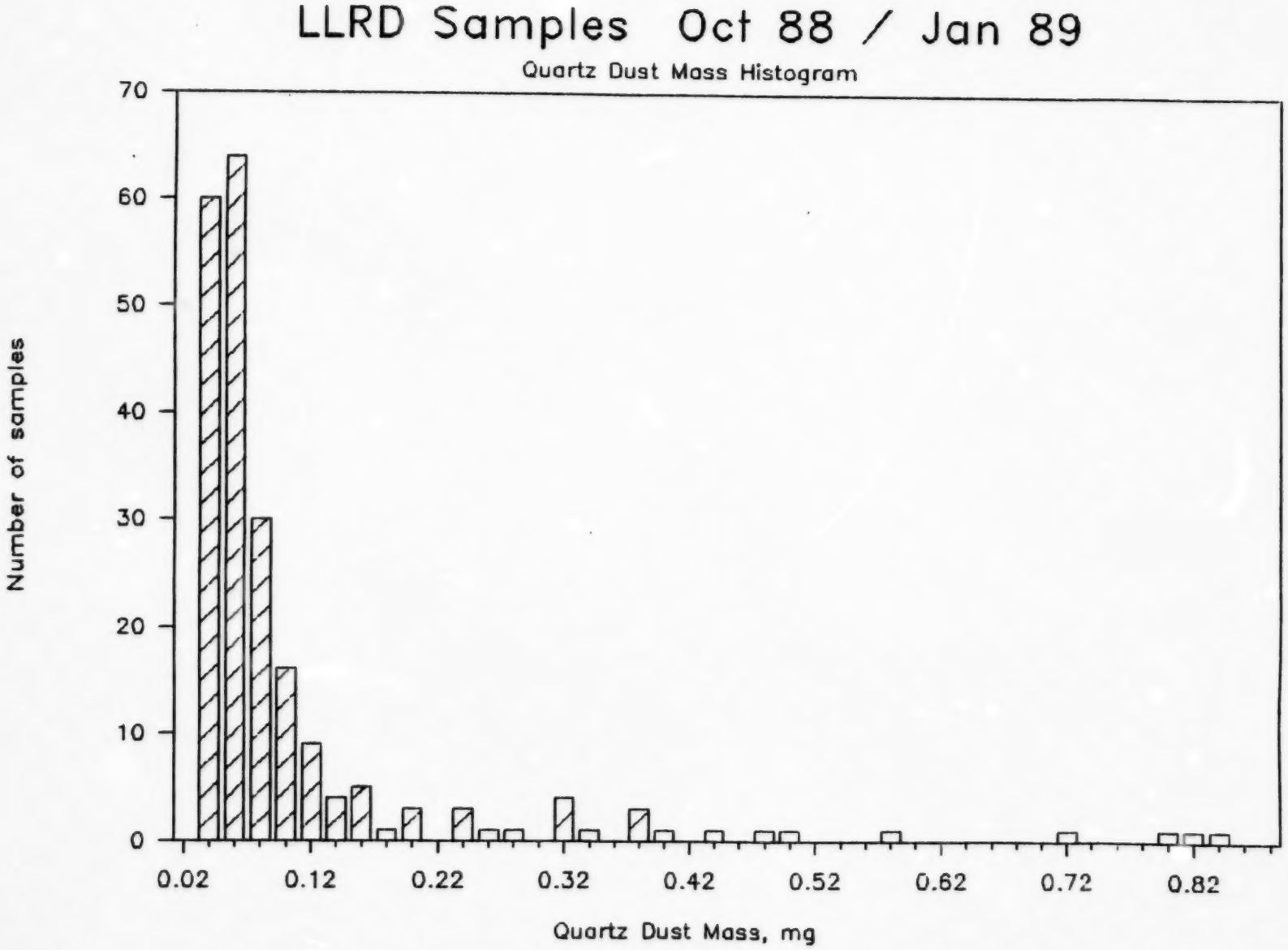

Fig. 5 - Quartz dust mass frequency distribution for the second sample population.

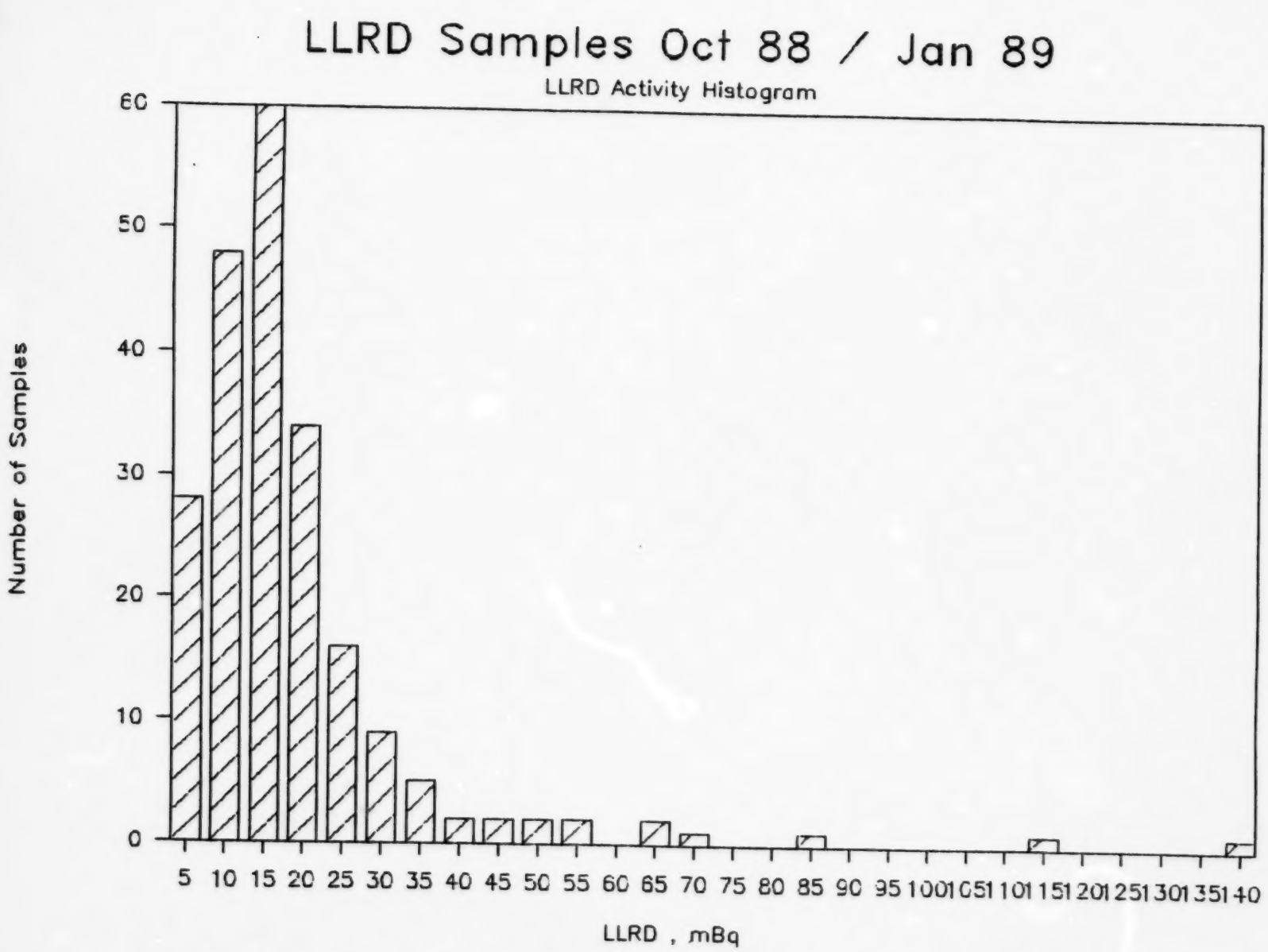

Fig. 6 - Long-Lived Radioactive Dust (LLRD) frequency distribution for the second sample population.

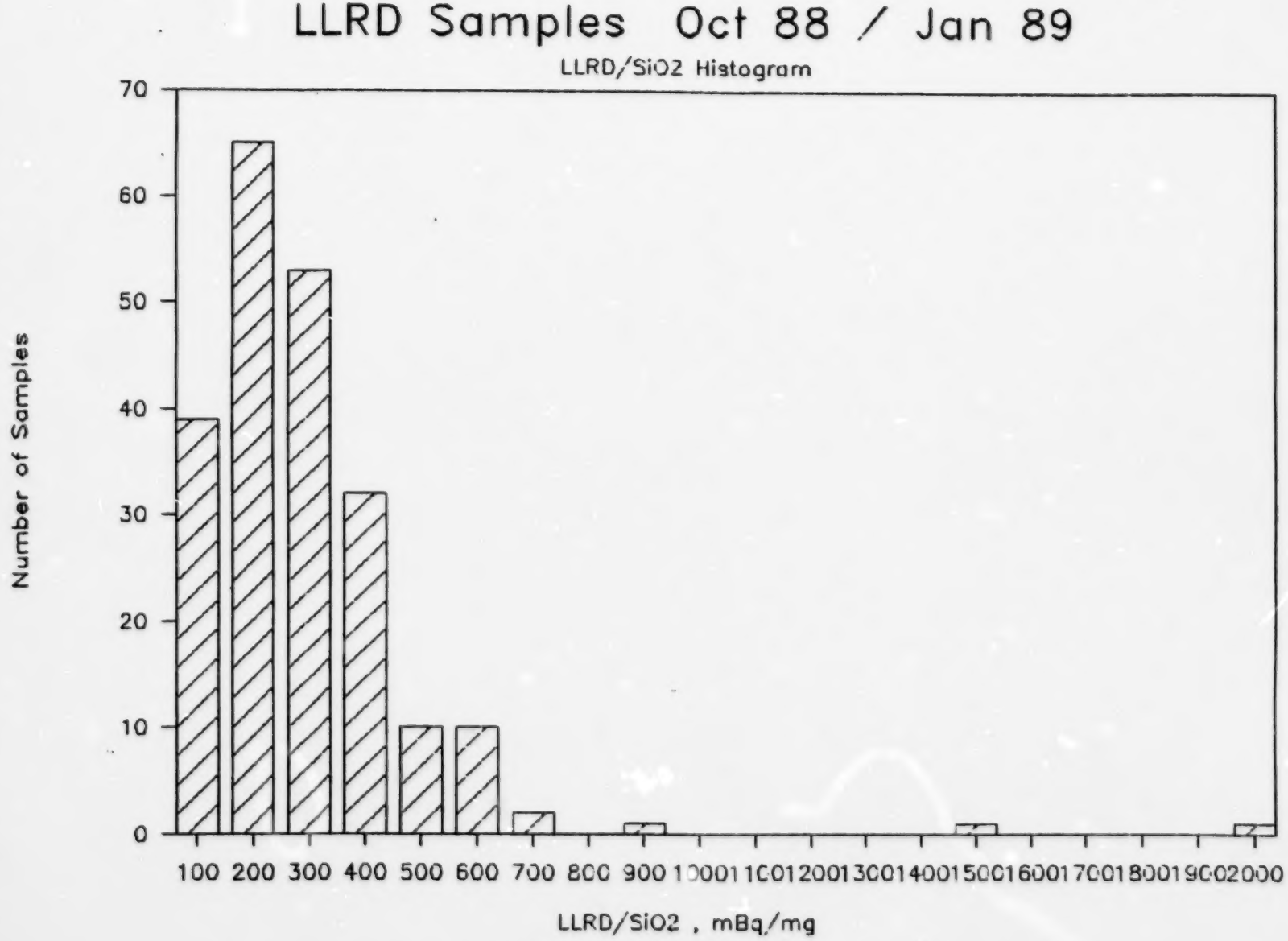

Fig. 7 - Long-Lived Radioactive Dust (LLRD) to silica dust (SiO_2) ratio frequency distribution for the second sample population.

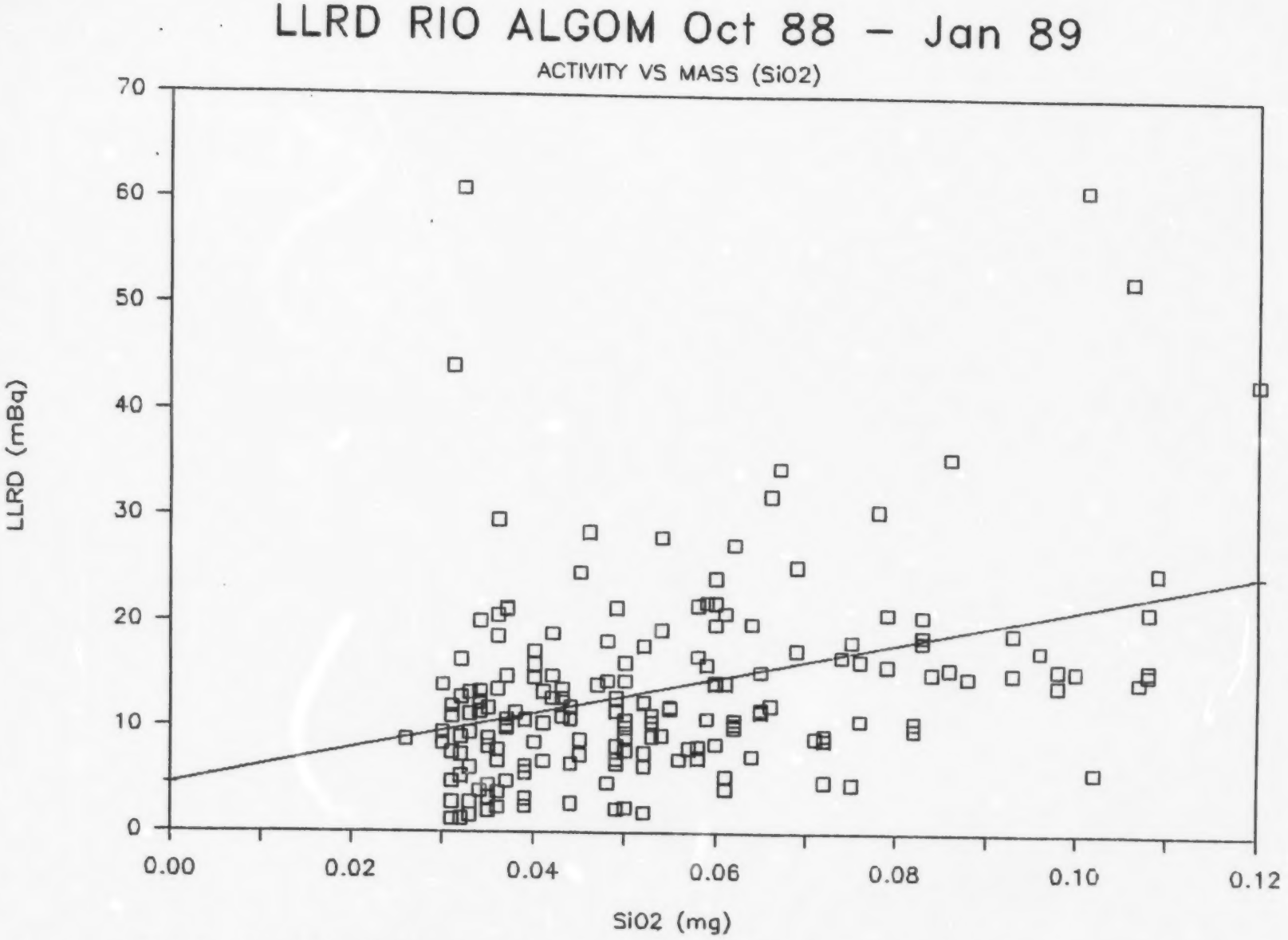

Fig. 8 - Long-Lived Radioactive Dust (LLRD) versus silica dust mass (SiO_2) for the second sample population. Also shown is the best fitted line through the data points.

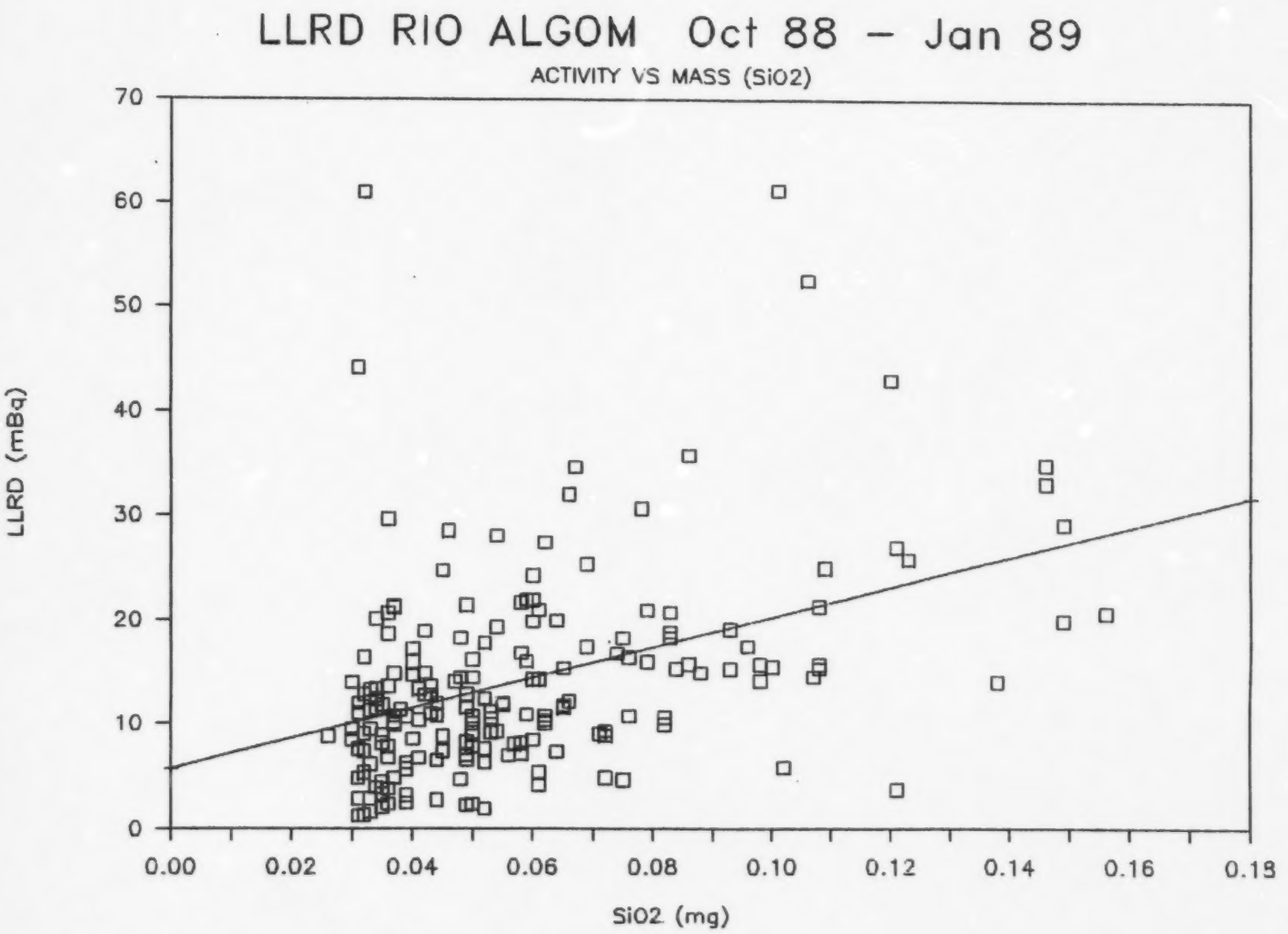

Fig. 9 - Long-Lived Radioactive Dust (LLRD) versus silica dust mass (SiO_2) for the second sample population. Also shown is the best fitted line through the data points.

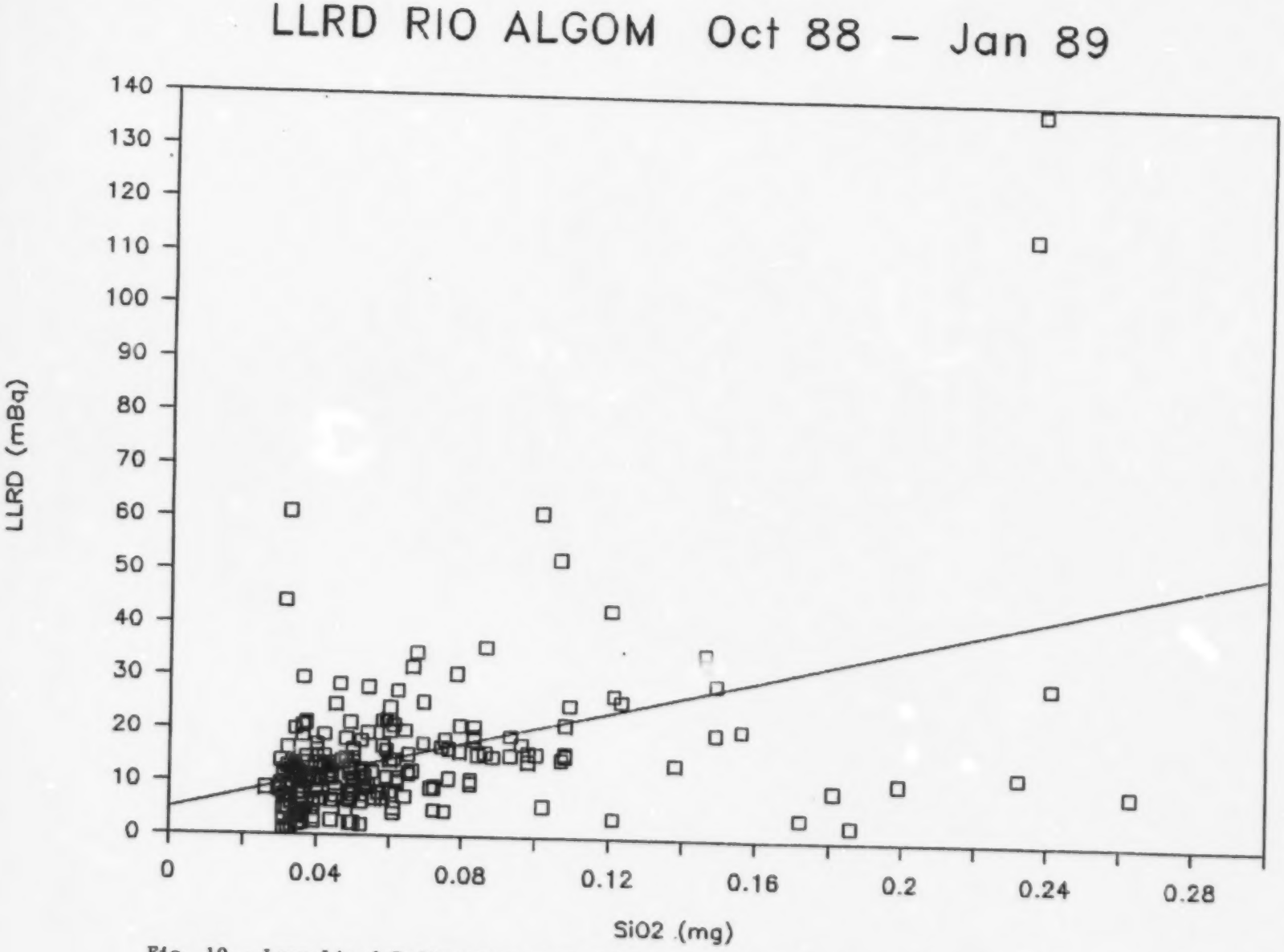

Fig. 10 - Long-Lived Radioactive Dust (LLRD) versus silica dust mass (SiO_2) for the second sample population. Also shown is the best fitted line through the data points.

Table 1 - Long-Lived Radioactive Dust (LLRD) and silica dust (SiO_2) data from underground samples taken during the period Jan. 1987 to June 1988.

S #	RD (mg)	SiO2 (mg)	Tri #	eff.	cpm (g)	B (ccm)	cpm(g)-B(ccm)	mBq	LLLD/SiO2 (mBq/mg)
A 748	0.22	0.181	5	0.4413	0.778	0.281	0.497	18.77	103.70
A 768	0.58	0.043	6	0.4475	0.311	0.183	0.129	4.77	110.97
A 769	0.94	0.125	7	0.4386	0.522	0.175	0.347	13.19	105.49
A 699	0.23	0.115	6	0.4475	0.811	0.183	0.628	23.39	203.38
A 700	0.81	0.048	7	0.4386	0.589	0.175	0.414	15.73	327.75
A 701	0.86	0.101	4	0.4471	0.567	0.185	0.382	14.24	140.99
A 706	0.09	0.068	5	0.4413	0.400	0.281	0.119	4.49	66.09
A 824	0.77	0.059	6	0.4475	0.356	0.183	0.173	6.44	109.21
A 857	0.81	0.053	7	0.4386	0.400	0.175	0.225	8.55	161.32
A 697	0.49	0.045	4	0.4471	0.500	0.185	0.315	11.74	260.94
A 739	0.53	0.168	6	0.4475	0.744	0.183	0.561	20.89	124.37
A 787	0.11	0.03	7	0.4386	0.344	0.175	0.169	6.42	214.06
A 800	0.34	0.076	4	0.4471	0.567	0.185	0.382	14.24	187.37
A 801	0.27	0.049	5	0.4413	0.478	0.281	0.197	7.44	151.84
A 802	0.51	0.074	6	0.4475	0.600	0.183	0.417	15.53	209.87
A 803	0.63	0.057	7	0.4386	0.422	0.175	0.247	9.39	164.67
A 804	0.46	0.058	4	0.4471	0.400	0.185	0.215	8.01	138.19
A 805	0.54	0.074	5	0.4413	0.700	0.281	0.419	15.82	213.84
A 819	0.17	0.06	6	0.4475	0.356	0.183	0.173	6.44	107.39
A 820	0.62	0.168	7	0.4386	1.044	0.175	0.869	33.02	196.56
A 821	0.15	0.043	4	0.4471	0.400	0.185	0.215	8.01	186.39
A 826	0.81	0.212	5	0.4413	1.378	0.281	1.097	41.43	195.43
A 730	0.31	0.096	4	0.4471	0.433	0.185	0.249	9.24	96.30
A 732	0.36	0.034	5	0.4413	0.567	0.281	0.286	10.80	317.69
A 733	0.52	0.086	6	0.4475	0.367	0.183	0.184	6.85	79.68
A 735	0.16	0.076	7	0.4386	0.644	0.175	0.469	17.82	234.50
A 794	0.45	0.045	4	0.4471	0.400	0.185	0.215	8.01	178.10
A 799	0.71	0.068	5	0.4413	0.667	0.281	0.386	14.58	214.38
A 818	0.11	0.031	6	0.4475	0.489	0.183	0.306	11.40	367.63
A 775	0.44	0.032	5	0.4413	0.344	0.281	0.063	2.38	74.35
A 784	0.24	0.034	4	0.4471	0.844	0.185	0.659	24.57	722.52
A 786	0.1	0.034	5	0.4413	0.678	0.281	0.397	14.99	440.99
A 810	0.36	0.03	6	0.4475	0.711	0.183	0.528	19.66	655.49
A 720	0.69	0.042	7	0.4386	0.467	0.175	0.292	11.10	264.19
A 757	0.22	0.032	4	0.4471	0.433	0.185	0.248	9.24	288.90
A 584	0.43	0.135	5	0.4413	1.644	0.281	1.363	51.48	381.31
A 633	0.29	0.064	6	0.4475	0.433	0.183	0.25	9.31	145.48
A 634	0.26	0.087	7	0.4386	0.456	0.175	0.281	10.68	122.73
A 635	0.49	0.078	4	0.4471	0.556	0.185	0.371	13.83	177.31
A 637	0.31	0.044	6	0.4475	0.300	0.183	0.117	4.36	99.04
A 640	0.29	0.075	7	0.4386	0.422	0.175	0.247	9.39	125.15
A 642	0.71	0.068	4	0.4471	0.711	0.185	0.526	19.61	288.35
A 643	0.59	0.054	5	0.4413	0.489	0.281	0.208	7.86	145.47
A 646	0.54	0.071	6	0.4475	0.711	0.183	0.528	19.66	276.97
A 651	0.81	0.038	4	0.4471	0.333	0.185	0.148	5.52	145.19
A 652	0.84	0.057	5	0.4413	0.700	0.281	0.419	15.82	277.62
A 653	0.3	0.085	6	0.4475	0.333	0.183	0.15	5.59	65.72
A 654	0.2	0.067	7	0.4386	0.267	0.175	0.092	3.50	52.18
A 655	0.79	0.045	4	0.4471	0.544	0.185	0.359	13.38	297.39
A 672	0.2	0.046	5	0.4413	0.633	0.281	0.352	13.29	289.00
A 673	0.22	0.075	6	0.4475	0.567	0.193	0.384	14.30	190.69
A 674	0.26	0.059	7	0.4386	0.822	0.175	0.647	24.59	416.71
A 682	0.48	0.054	4	0.4471	0.378	0.185	0.193	7.19	133.23
A 688	0.75	0.036	5	0.4413	0.556	0.281	0.275	10.39	288.50
A 693	0.53	0.048	6	0.4475	0.478	0.193	0.295	10.99	228.90
A 709	0.63	0.075	7	0.4386	0.378	0.175	0.203	7.71	102.85
A 710	0.74	0.106	4	0.4471	0.756	0.185	0.571	21.29	200.80
A 713	0.63	0.043	5	0.4413	0.322	0.281	0.041	1.55	36.01

Table 1 - Cont.

S #	RD (ag)	SiO2 (ag)	Tri #	eff.	cpm (g)	B (cpm)	cpm(g)-B(cpm)	aBq	LLLD/SiO2 (aBq/ag)
A 714	0.36	0.062	6	0.4475	0.367	0.183	0.184	6.85	110.53
A 578	0.06	0.054	4	0.4471	0.533	0.185	0.348	12.97	240.23
A 579	0.19	0.086	5	0.4413	0.478	0.281	0.197	7.44	86.51
A 580	0.2	0.044	6	0.4475	0.800	0.183	0.617	22.98	522.26
A 581	0.17	0.041	7	0.4386	0.767	0.175	0.592	22.50	548.68
A 593	0.33	0.087	4	0.4471	0.667	0.185	0.482	17.97	206.52
A 594	0.18	0.048	5	0.4413	0.433	0.281	0.152	5.74	119.60
A 598	0.39	0.2	6	0.4475	0.733	0.183	0.55	20.48	102.42
A 600	1.68	0.532	4	0.4471	2.989	0.185	2.804	104.53	196.48
A 601	1.03	0.104	5	0.4413	0.544	0.281	0.263	9.93	95.51
A 611	0.28	0.109	6	0.4475	0.378	0.183	0.195	7.26	66.63
A 613	0.54	0.114	7	0.4386	0.689	0.175	0.514	19.53	171.33
A 615	0.12	0.048	4	0.4471	0.344	0.185	0.159	5.93	123.48
A 949	0.14	0.04	6	0.4475	0.755	0.183	0.572	21.30	532.59
A 971	0.17	0.035	7	0.4386	0.500	0.175	0.325	12.35	352.85
A 978	0.2	0.076	4	0.4471	1.333	0.185	1.148	42.79	563.08
A 979	0.28	0.092	7	0.4386	1.589	0.175	1.414	53.73	584.04
A 980	0.16	0.065	6	0.4475	1.067	0.183	0.884	32.92	506.52
A 998	0.35	0.044	4	0.4471	1.511	0.185	1.326	49.43	1123.40
A 999	0.31	0.069	5	0.4413	1.822	0.281	1.541	58.20	843.47
B 2	0.74	0.432	5	0.4413	2.956	0.281	2.675	101.03	233.86
A 917	0.69	0.035	4	0.4471	0.200	0.185	0.015	0.56	15.98
A 918	0.1	0.03	5	0.4413	0.367	0.281	0.086	3.25	108.27
A 923	0.09	0.038	7	0.4386	0.422	0.175	0.247	9.39	247.00
A 932	0.49	0.035	4	0.4471	0.622	0.185	0.437	16.29	465.43
A 935	0.66	0.153	5	0.4413	1.667	0.281	1.386	52.35	342.13
A 936	0.93	0.142	6	0.4475	0.944	0.183	0.761	28.34	199.60
A 942	0.22	0.091	7	0.4386	1.256	0.175	1.081	41.08	451.40
A 947	0.3	0.039	5	0.4413	0.744	0.281	0.463	17.49	448.36
A 852	0.15	0.032	4	0.4471	0.478	0.185	0.293	10.92	341.32
A 892	0.32	0.052	5	0.4413	0.300	0.281	0.019	0.72	13.80
A 889	0.31	0.16	6	0.4475	0.767	0.183	0.584	21.75	135.94
A 893	0.12	0.052	7	0.4386	0.567	0.175	0.392	14.90	286.46
A 895	0.72	0.125	4	0.4471	0.611	0.185	0.426	15.88	127.04
A 938	0.23	0.081	5	0.4413	1.056	0.281	0.775	29.27	361.35
A 943	1.71	0.036	4	0.4471	0.444	0.185	0.259	9.65	268.19
A 848	0.4	0.113	6	0.4475	1.633	0.183	1.45	54.00	477.91
A 705	0.46	0.039	5	0.4413	0.678	0.281	0.397	14.99	384.45
A 828	0.37	0.046	7	0.4386	0.489	0.175	0.314	11.93	259.39
A 829	0.44	0.077	4	0.4471	0.633	0.185	0.448	16.70	216.89
A 830	0.33	0.068	5	0.4413	0.667	0.281	0.386	14.58	214.38
A 831	0.16	0.041	6	0.4475	0.344	0.183	0.161	6.00	146.25
A 838	0.08	0.059	4	0.4471	0.378	0.185	0.193	7.19	121.94
A 839	0.68	0.076	5	0.4413	0.644	0.281	0.363	13.71	180.39
A 840	0.38	0.091	6	0.4475	0.633	0.183	0.45	16.76	184.17
A 843	0.16	0.059	7	0.4386	0.711	0.175	0.536	20.37	345.22
A 868	0.36	0.104	4	0.4471	1.167	0.185	0.982	36.61	351.98
A 879	0.32	0.035	4	0.4471	0.478	0.185	0.293	10.92	312.06
A 886	0.24	0.031	5	0.4413	0.344	0.281	0.063	2.38	76.77
A 887	0.2	0.033	6	0.4475	0.444	0.183	0.261	9.72	294.57
A 903	0.41	0.059	7	0.4386	0.511	0.175	0.336	12.77	216.41
A 908	0.4	0.037	6	0.4475	0.533	0.183	0.35	13.04	352.31
A 959	0.2	0.048	7	0.4386	0.222	0.175	0.047	1.79	37.21
A 960	0.77	0.112	7	0.4386	1.111	0.175	0.936	35.57	317.57
A 964	0.17	0.034	4	0.4471	0.522	0.185	0.337	12.56	369.48
A 965	0.74	0.1	5	0.4413	0.544	0.281	0.263	9.93	99.33
A 725	0.22	0.055	5	0.4413	0.367	0.281	0.086	3.25	59.05
A 746	0.67	0.055	6	0.4475	0.578	0.183	0.395	14.71	267.48

Table 1 - Cont.

S #	RD (ag)	SiO2 (ag)	Tri #	eff.	cpm (g)	B (cpm)	cpm(g)-B(cpm)	mBq	LLLD/SiO2 (mBq/ag)
A 145	1.98	0.884	4	0.4471	2.933	0.185	2.748	102.44	115.88
A 147	0.55	0.074	5	0.4413	0.756	0.281	0.475	17.94	242.42
A 148	0.51	0.091	6	0.4475	0.667	0.183	0.484	18.03	198.09
A 157	0.34	0.083	6	0.4475	0.756	0.183	0.573	21.34	257.12
A 175	0.33	0.057	7	0.4386	0.844	0.175	0.669	25.42	446.00
A 867	0.25	0.069	7	0.4386	1.656	0.175	1.481	56.28	815.62
A 868	0.15	0.045	4	0.4471	0.867	0.185	0.682	25.42	564.96
A 70	0.47	0.056	7	0.4386	0.300	0.175	0.125	4.75	84.82
A 86	0.11	0.032	4	0.4471	0.411	0.185	0.226	8.42	263.27
A 91	0.21	0.047	5	0.4413	0.811	0.281	0.53	20.02	425.89
A 102	0.13	0.052	6	0.4475	0.567	0.183	0.384	14.30	275.03
A 111	0.1	0.032	7	0.4386	0.556	0.175	0.381	14.48	452.43
A 112	0.19	0.045	4	0.4471	0.411	0.185	0.226	8.42	187.21
A 113	0.08	0.03	5	0.4413	0.356	0.281	0.075	2.83	94.42
A 114	0.21	0.087	6	0.4475	0.600	0.183	0.417	15.53	178.51
A 118	0.85	0.03	4	0.4471	0.678	0.185	0.493	18.38	612.59
860	1.63	0.945	5	0.4413	4.389	0.281	4.108	155.15	164.18
861	4.14	0.088	6	0.4475	1.933	0.183	1.75	65.18	740.65
955	1.16	0.16	5	0.4413	0.556	0.281	0.275	10.39	64.91
966	0.12	0.04	6	0.4475	0.233	0.183	0.05	1.86	46.55
969	0.18	0.044	5	0.4413	0.478	0.281	0.197	7.44	169.09
972	0.16	0.057	6	0.4475	0.456	0.183	0.273	10.17	178.38
986	0.53	0.034	7	0.4386	0.300	0.175	0.125	4.75	139.70
996	0.31	0.037	4	0.4471	0.333	0.185	0.148	5.52	149.11
997	0.29	0.043	5	0.4413	0.433	0.281	0.152	5.74	133.50
999	0.48	0.067	6	0.4475	0.544	0.183	0.361	13.45	200.67
A 7	0.36	0.055	5	0.4413	0.589	0.281	0.308	11.63	211.50
A 8	0.28	0.041	6	0.4475	0.478	0.183	0.295	10.99	267.97
946	1.24	0.181	7	0.4386	0.633	0.175	0.458	17.40	96.15
761	0.11	0.078	6	0.4475	0.500	0.183	0.317	11.81	151.36
915	0.28	0.049	4	0.4471	0.344	0.185	0.159	5.93	120.96
921	0.28	0.108	6	0.4475	0.822	0.183	0.639	23.80	220.36
924	0.23	0.048	7	0.4386	0.633	0.175	0.458	17.40	362.58
925	1.69	1.161	4	0.4471	3.400	0.185	3.215	119.85	103.23
926	1.15	0.812	5	0.4413	2.600	0.281	2.319	87.58	107.86
934	0.71	0.031	6	0.4475	0.556	0.183	0.373	13.89	448.13
935	1.49	0.1	7	0.4386	0.733	0.175	0.558	21.20	212.04
809		0.031	4	0.4471	0.833	0.185	0.648	24.16	779.22
849	0.27	0.035	7	0.4386	0.322	0.175	0.147	5.59	159.60
857	0.28	0.131	4	0.4471	0.467	0.185	0.282	10.51	80.25
872	0.5	0.046	5	0.4413	0.567	0.281	0.286	10.80	234.81
874	0.3	0.066	6	0.4475	0.644	0.183	0.461	17.17	260.14
875	0.17	0.053	7	0.4386	0.567	0.175	0.392	14.90	281.05
886	0.1	0.089	5	0.4413	0.744	0.281	0.463	17.49	196.47
906	0.23	0.045	4	0.4471	0.511	0.185	0.326	12.15	270.05
902	0.07	0.033	6	0.4475	0.378	0.183	0.195	7.26	220.08
903	1.29	0.53	7	0.4386	2.967	0.175	2.792	106.10	200.18
655	0.05	0.04	4	0.4471	0.433	0.185	0.248	9.24	231.12
657	0.05	0.047	5	0.4413	0.656	0.281	0.375	14.16	301.33
659	0.17	0.083	6	0.4475	0.622	0.183	0.439	16.35	196.99
663	0.16	0.069	7	0.4386	0.589	0.175	0.414	15.73	228.00
664	0.07	0.047	4	0.4471	0.767	0.185	0.582	21.70	461.60
667	0.06	0.036	6	0.4475	0.244	0.183	0.061	2.27	63.11
756	0.21	0.052	5	0.4413	0.989	0.281	0.708	26.74	514.21
775	0.17	0.038	4	0.4471	0.411	0.185	0.226	8.42	221.70
778	0.01	0.032	4	0.4471	0.422	0.185	0.237	8.83	276.08
779	0.13	0.056	5	0.4413	0.656	0.281	0.375	14.16	252.91
816	0.17	0.043	6	0.4475	0.544	0.183	0.361	13.45	312.68

Table 1 - Cont.

S #	RB (ag)	SiO2 (ag)	Tri #	eff.	cpm (g)	B (cpm)	cpm(g)-B(cpm)	mBq	LLLD/SiO2 (mBq/ag)
818	0.44	0.031	7	0.4386	0.356	0.175	0.181	6.88	221.87
826	0.6	0.054	4	0.4471	0.478	0.185	0.293	10.92	202.26
828	0.18	0.032	5	0.4413	0.522	0.281	0.241	9.10	284.43
832	0.28	0.037	6	0.4475	0.333	0.183	0.15	5.59	150.99
836	0.21	0.038	7	0.4386	0.289	0.175	0.114	4.33	114.00
838	0.27	0.039	4	0.4471	0.600	0.185	0.415	15.47	396.67
843	0.16	0.281	6	0.4475	2.989	0.183	2.806	104.51	371.91
844	0.37	0.048	5	0.4413	0.722	0.281	0.441	16.66	346.99
846	0.06	0.032	7	0.4386	0.633	0.175	0.458	17.40	543.87
766	0.34	0.031	4	0.4471	0.644	0.185	0.459	17.11	551.94
773	0.69	0.099	5	0.4413	0.667	0.281	0.386	14.58	147.25
774	0.91	0.03	5	0.4413	0.322	0.281	0.041	1.55	51.62
787	0.17	0.059	7	0.4386	0.733	0.175	0.558	21.20	359.39
798		0.048	4	0.4471	2.278	0.185	2.093	78.02	1625.44
732	0.28	0.069	6	0.4475	0.967	0.183	0.784	29.20	423.19
781	0.38	0.072	7	0.4386	0.678	0.175	0.503	19.11	265.47
783	0.46	0.08	4	0.4471	0.622	0.185	0.437	16.29	203.63
738	0.17	0.065	5	0.4413	0.500	0.281	0.219	8.27	127.25
739	0.01	0.039	6	0.4475	0.244	0.183	0.061	2.27	58.25
744	0.2	0.034	7	0.4386	0.344	0.175	0.169	6.42	188.88
745	0.32	0.031	7	0.4386	0.400	0.175	0.225	8.55	275.80
A 324	0.6	0.054	4	0.4471	0.556	0.185	0.371	13.83	256.11
A 325	0.35	0.061	5	0.4413	0.633	0.281	0.352	13.29	217.94
A 332	0.07	0.05	6	0.4475	0.500	0.183	0.317	11.81	236.13
A 333	0.6	0.335	7	0.4386	1.833	0.175	1.658	63.00	188.07
A 348	0.44	0.042	4	0.4471	0.378	0.185	0.193	7.19	171.30
A 349	0.39	0.047	5	0.4413	0.422	0.281	0.141	5.33	113.30
A 350	0.29	0.092	4	0.4471	1.611	0.185	1.426	53.16	577.80
A 357	0.12	0.039	5	0.4413	1.044	0.281	0.763	28.82	738.88
A 265	1.3	0.127	6	0.4475	0.833	0.183	0.65	24.21	190.62
A 281	0.1	0.03	7	0.4386	0.856	0.175	0.681	25.88	862.59
A 282	0.34	0.145	6	0.4475	0.500	0.183	0.317	11.81	81.42
A 283	0.07	0.05	7	0.4386	0.222	0.175	0.047	1.79	35.72
A 284	0.23	0.07	7	0.4386	0.311	0.175	0.136	5.17	73.83
A 287	0.17	0.063	6	0.4475	0.378	0.183	0.195	7.26	115.28
A 168	0.34	0.037	5	0.4413	0.411	0.281	0.13	4.91	132.70
A 202	0.44	0.033	4	0.4471	0.433	0.185	0.248	9.24	280.14
A 221	0.48	0.037	4	0.4471	0.300	0.185	0.115	4.29	115.86
A 223	0.22	0.065	5	0.4413	0.733	0.281	0.452	17.07	262.63
A 224	0.97	0.162	6	0.4475	0.444	0.183	0.261	9.72	60.00
A 226	0.6	0.059	7	0.4386	0.644	0.175	0.469	17.82	302.07
A 196	0.29	0.038	4	0.4471	0.922	0.185	0.737	27.47	722.98
A 199	0.24	0.042	5	0.4413	0.767	0.281	0.486	18.35	437.02
A 217	0.66	0.034	6	0.4475	0.678	0.183	0.495	18.44	542.23
A 218	0.73	0.07	7	0.4386	1.167	0.175	0.992	37.70	538.51
A 255	0.65	0.041	4	0.4471	0.456	0.185	0.271	10.10	246.39
A 104	0.06	0.05	5	0.4413	0.756	0.281	0.475	17.94	358.79
A 110	0.2	0.031	6	0.4475	0.556	0.183	0.373	13.89	448.13
A 127	0.41	0.096	7	0.4386	1.322	0.175	1.147	43.59	454.02
A 128	0.21	0.054	4	0.4471	0.978	0.185	0.793	29.56	547.42
A 132	0.17	0.05	5	0.4413	1.367	0.281	1.086	41.02	820.30
A 150	1.13	0.03	6	0.4475	0.700	0.183	0.517	19.26	641.84
A 151	1.84	0.053	7	0.4386	0.789	0.175	0.614	23.33	440.22
A 170	0.56	0.06	6	0.4475	0.189	0.183	0.006	0.22	3.72
A 184	0.36	0.116	4	0.4471	0.944	0.185	0.759	28.29	243.91
A 190	0.45	0.034	5	0.4413	0.622	0.281	0.341	12.88	378.78
A 140		0.035	4	0.4471	0.411	0.185	0.226	8.42	240.70
A 142	0.39	0.03	5	0.4413	0.344	0.281	0.063	2.38	79.31

Table 1 - Cont.

S #	RD (mg)	SiO2 (mg)	Tri #	eff.	cpm (g)	B (cpm)	cpm(g)-B(cpm)	mBq	LLLD/SiO2 (mBq/mg)
A 143	0.5	0.109	6	0.4475	0.411	0.183	0.228	8.49	77.90
A 144	0.45	0.087	7	0.4386	0.489	0.175	0.314	11.93	137.15
A 562	0.31	0.099	4	0.4471	1.144	0.185	0.959	35.75	361.10
A 582	0.2	0.079	5	0.4413	0.978	0.281	0.697	26.32	333.21
A 587	0.32	0.081	7	0.4386	1.167	0.175	0.992	37.70	465.38
A 589	0.19	0.065	4	0.4471	0.544	0.185	0.359	13.38	205.89
A 590	0.25	0.04	5	0.4413	0.567	0.281	0.286	10.80	270.04
A 591	0.66	0.166	6	0.4475	0.700	0.183	0.517	19.26	115.99
A 602	0.42	0.084	7	0.4386	0.889	0.175	0.714	27.13	323.00
A 605	1.13	0.03	4	0.4471	0.389	0.185	0.204	7.60	253.49
A 607	0.01	0.036	5	0.4413	0.789	0.281	0.508	19.19	532.94
A 608	2.12	0.037	6	0.4475	0.322	0.183	0.139	5.18	139.92
A 609	0.91	0.109	7	0.4386	1.033	0.175	0.858	32.60	299.12
A 610	0.9	0.069	4	0.4471	0.578	0.185	0.393	14.65	212.32
A 539	1.08	0.082	5	0.4413	0.922	0.281	0.641	24.21	295.23
A 540	0.06	0.037	6	0.4475	0.378	0.183	0.195	7.26	196.29
A 541	0.43	0.15	7	0.4386	0.633	0.175	0.458	17.40	116.03
A 542	0.14	0.078	7	0.4386	0.367	0.175	0.192	7.30	93.54
A 543	0.04	0.058	6	0.4475	0.189	0.183	0.006	0.22	3.85
A 545	0.54	0.045	7	0.4386	0.489	0.175	0.314	11.93	265.15
A 549	0.35	0.044	4	0.4471	0.378	0.185	0.193	7.19	163.51
A 552	0.42	0.142	5	0.4413	0.656	0.281	0.375	14.16	99.74
A 553	0.09	0.049	6	0.4475	0.322	0.183	0.139	5.18	105.65
A 554	0.67	0.365	7	0.4386	1.678	0.175	1.503	57.11	156.48
A 487	1.28	0.033	4	0.4471	0.344	0.185	0.159	5.93	179.61
A 490	0.12	0.08	5	0.4413	0.478	0.281	0.197	7.44	93.00
A 492	0.11	0.065	7	0.4386	0.444	0.175	0.269	10.22	157.26
A 494	0.14	0.044	4	0.4471	0.456	0.185	0.271	10.10	229.59
A 434	0.22	0.031	7	0.4386	0.267	0.175	0.092	3.50	112.77
A 435	0.19	0.036	4	0.4471	0.344	0.185	0.159	5.93	164.64
A 438	0.3	0.131	5	0.4413	0.456	0.281	0.175	6.61	50.45
A 439	0.57	0.053	7	0.4386	0.711	0.175	0.536	20.37	384.30
A 451	0.26	0.065	6	0.4475	0.500	0.183	0.317	11.81	181.64
A 452	0.3	0.052	7	0.4386	0.444	0.175	0.269	10.22	196.58
A 336	0.15	0.064	7	0.4386	0.244	0.175	0.069	2.62	40.97
A 384	0.2	0.037	4	0.4471	0.222	0.185	0.037	1.38	37.28
A 388	0.21	0.064	6	0.4475	0.411	0.183	0.228	8.49	132.68
A 413	0.06	0.031	5	0.4413	0.378	0.281	0.097	3.66	118.17
A 414	0.29	0.084	4	0.4471	1.022	0.185	0.837	31.20	371.44
A 267	0.27	0.065	4	0.4471	0.411	0.185	0.226	8.42	129.61
A 269	0.2	0.041	5	0.4413	0.533	0.281	0.252	9.52	232.13
A 366	1.09	0.048	6	0.4475	0.233	0.183	0.05	1.86	38.80
A 368	0.23	0.046	5	0.4413	0.756	0.281	0.475	17.94	389.99
A 369	0.29	0.064	7	0.4386	0.744	0.175	0.569	21.62	337.84
A 396	0.15	0.08	5	0.4413	0.622	0.281	0.341	12.88	160.98
A 398	0.21	0.048	4	0.4471	0.922	0.185	0.737	27.47	572.36
A 400	0.17	0.041	5	0.4413	0.800	0.281	0.519	19.60	478.08
A 409	0.41	0.152	6	0.4475	1.200	0.183	1.017	37.88	249.19
A 410	0.38	0.098	7	0.4386	0.822	0.175	0.647	24.59	250.88
A 241	0.11	0.041	4	0.4471	0.500	0.185	0.315	11.74	286.40
A 574	1.38	0.344	7	0.4386	1.767	0.175	1.592	60.50	175.86
A 576	0.85	0.133	4	0.4471	1.011	0.185	0.826	30.79	231.51
A 583	0.54	0.166	5	0.4413	2.156	0.281	1.875	70.81	426.59
A 511	0.15	0.034	4	0.4471	0.500	0.185	0.315	11.74	345.36
A 569	0.01	0.034	6	0.4475	0.833	0.183	0.65	24.21	712.02
A 572	0.74	0.042	7	0.4386	0.789	0.175	0.614	23.33	555.52
A 501	0.8	0.12	5	0.4413	1.156	0.281	0.875	33.05	275.39
A 502	0.39	0.131	6	0.4475	0.800	0.183	0.617	22.98	175.42

Table 1 - Cont.

S #	RD (mg)	SiO2 (mg)	Tri #	eff.	cpm (g)	B (cpm)	cpm(g)-B(cpm)	mBq	LLLD/SiO2 (mBq/mg)
A 505	0.26	0.049	7	0.4386	0.611	0.175	0.436	16.57	338.12
A 445	0.39	0.091	4	0.4471	0.844	0.185	0.659	24.57	269.95
A 519	1	0.034	5	0.4413	0.533	0.281	0.252	9.52	279.92
A 523	1.14	0.033	6	0.4475	0.478	0.183	0.295	10.99	332.94
A 533	0.1	0.043	7	0.4386	0.444	0.175	0.269	10.22	237.72
A 535	0.72	0.067	5	0.4413	0.578	0.281	0.297	11.22	167.42
A 537	0.96	0.086	6	0.4475	0.778	0.183	0.595	22.16	257.68
A 628	0.06	0.03	4	0.4471	0.278	0.217	0.061	2.27	75.80
A 658	0.14	0.036	5	0.4413	0.656	0.25	0.406	15.33	425.93
A 570	0	0.16	5	0.4413	1.427	0.281	1.146	43.28	270.51
A 573	0.67	0.099	7	0.4386	0.333	0.15	0.183	6.95	70.24
A 117	0.21	0.033	7	0.4386	0.233	0.216	0.017	0.65	19.58
A 450	0.36	0.057	4	0.4471	0.578	0.15	0.428	15.95	279.91
A 455	0.34	0.123	5	0.4413	1.1	0.25	0.85	32.10	260.99
A 456	0.22	0.07	6	0.4475	0.7	0.083	0.617	22.98	328.28
A 478	0.26	0.054	7	0.4386	0.289	0.217	0.072	2.74	50.67
A 321	1.55	0.273	4	0.4471	1.722	0.185	1.537	57.30	209.87
A 317	0.11	0.045	5	0.4413	0.733	0.281	0.452	17.07	379.35

Note: The symbols S#, RD, cpm(g) and B(cpm) stand, respectively, for sample number, respirable dust, gross α-particle count in counts per minute, background (counts per minute). The symbols Tri# and eff. refer, respectively, to the α-particle counter used and its respective efficiency.

Table 2 - Long-Lived Radioactive Dust (LLRD) and silica dust (SiO_2) data from underground samples taken during the period October 1988 to January 1989.

Sample #	Long Lived Radioactive Dust (LLRD)		Resp.	Quartz	LLRD	LLRD/SiO2
	cpm	dpm	Dust mg	Dust mg	aBq	aBq/mg
b332	0.194	0.437	0.35	0.032	7.283	227.594
b334	0.033	0.074	0.22	0.032	1.233	38.531
b337	0.183	0.398	1.22	0.036	6.633	184.250
b347	0.216	0.502	0.08	0.03	8.366	278.867
b348	0.239	0.538	0.12	0.071	8.966	126.282
b349	0.122	0.275	0.17	0.075	4.583	61.107
b350	0.350	0.763	0.05	0.042	12.708	302.571
b351	0.294	0.683	0.09	0.58	11.383	19.626
b358	0.188	0.424	0.57	0.48	7.066	14.721
b337	0.495	1.117	1.22	0.036	18.617	517.139
b634	0.495	1.078	0.47	0.72	17.967	24.954
b641	0.494	1.146	0.23	0.5	19.1	38.200
b642	0.077	0.173	0.26	0.31	2.883	9.300
b647	1.061	2.395	1.02	0.84	39.917	47.520
b650	0.584	1.273	0.48	0.108	21.217	196.454
b658	0.383	0.888	0.56	0.79	14.8	18.734
b660	0.511	1.153	0.3	0.054	19.217	355.870
b661	0.472	1.065	0.33	0.052	17.75	341.346
b667	0.406	0.884	0.11	0.037	14.733	398.189
b671	0.161	0.373	0.28	0.039	6.216	159.385
b676	0.555	1.252	0.49	0.079	20.867	264.139
b677	0.528	1.191	0.49	0.064	19.85	310.156
b704	0.384	0.836	0.63	0.03	13.933	464.433
b684	1.317	3.055	0.7	0.304	50.917	167.490
b583	0.088	0.198	0.8	0.802	3.3	4.115
b587	0.794	1.792	0.38	0.241	29.867	123.929
b589	0.033	0.071	0.38	0.031	1.183	38.161
b590	0.411	0.953	0.28	0.04	15.883	397.075
b592	1.622	3.661	0.3	0.032	61.017	1906.781
b618	0.305	0.688	0.32	0.049	11.466	234.000
b622	0.600	1.307	0.28	0.06	21.783	363.050
b717	0.367	0.851	0.14	0.37	14.183	38.332
b607	-0.100	-0.225	0.13	0.032	-3.75	-117.188
b608	0.139	0.313	0.32	0.061	5.216	85.508
b614	0.222	0.483	0.11	0.035	8.05	230.000
b617	1.733	4.020	0.8	0.434	67.001	154.380
b710	0.077	0.173	0.61	0.186	2.883	15.500

Table 2 - Cont.

b747	0.383	0.864	0.21	0.048	14.4	300.000
b748	0.067	0.145	0.18	0.039	2.416	61.949
b749	2.967	6.883	1.51	0.235	114.718	488.162
b735	0.316	0.713	0.33	0.044	11.883	270.068
b740	0.533	1.203	0.29	0.034	20.05	589.706
b742	0.389	0.847	0.68	0.098	14.116	144.041
b745	0.400	0.928	0.78	0.1	15.466	154.660
b686	0.550	1.241	0.46	0.156	20.683	132.583
b687	0.244	0.550	0.41	0.054	9.166	169.740
b688	0.211	0.459	0.32	0.05	7.65	153.000
b698	0.356	0.593	0.61	0.037	9.883	267.108
b728	0.205	0.462	0.2	0.036	7.7	213.889
b768	1.144	2.582	0.08	0.12	43.034	358.617
b769	0.711	1.549	0.27	0.123	25.817	209.894
b770	2.089	4.846	0.88	0.337	80.768	239.668
b771	0.217	0.489	0.56	0.049	8.15	166.327
b773	0.111	0.250	0.12	0.061	4.166	68.295
b774	0.000	0.000	0.03	0.034	0	0.000
b776	0.638	1.480	0.32	0.045	24.667	548.156
b785	0.406	0.916	0.29	0.108	15.266	141.352
b778	0.200	0.451	0.44	0.052	7.516	144.538
b782	0.500	1.089	0.55	0.075	18.15	242.000
b784	0.072	0.167	0.15	0.033	2.783	84.333
b752	0.239	0.539	0.1	0.032	8.983	280.719
b761	0.177	0.399	0.14	0.041	6.65	162.195
b762	0.311	0.677	0.18	0.038	11.283	296.921
b525	0.516	1.197	0.11	0.149	19.95	133.893
b528	0.284	0.641	0.33	0.044	10.683	242.795
b529	1.288	2.907	0.6	0.303	48.45	159.901
b552	0.089	0.193	0.08	0.035	3.216	91.886
b563	0.294	0.682	0.73	0.065	11.668	179.508
b843	0.555	1.252	0.35	0.061	20.867	342.082
b840	0.355	0.801	0.18	0.041	13.35	325.610
b841	0.461	1.004	0.24	0.058	16.733	288.500
b849	1.584	3.675	0.29	0.101	61.251	606.446
b857	0.255	0.575	0.7	0.263	9.583	36.437
b859	0.266	0.600	0.1	0.05	10	200.000
b860	0.261	0.568	0.56	0.181	9.466	52.298
b861	0.328	0.761	0.97	0.232	12.683	54.668
b862	0.111	0.250	0.53	0.172	4.166	24.221

Table 2 - Cont.

b819	0.266	0.600	0.46	0.062	10	161.290
b823	0.595	1.296	0.42	0.058	21.6	372.414
b826	0.895	2.076	0.42	0.067	34.6	516.418
b827	0.311	0.702	0.51	0.035	11.7	334.286
b828	0.777	1.753	0.82	0.149	29.217	196.087
b830	0.439	0.956	0.29	0.059	15.94	270.169
b834	0.228	0.529	0.28	0.072	8.816	122.444
b810	0.505	1.139	0.4	0 093	18.983	204.118
b812	0.727	1.641	0.33	0.062	27.35	441.129
b864	⅓.233	0.507	0.15	0.04	8.45	211.250
b835	0.534	1.238	0.31	0.083	20.663	248.952
b854	0.372	0.839	0.96	0.371	13.983	37.690
b855	0.294	0.663	0.64	0.199	11.05	55.528
b856	0.255	0.535	0.79	0.307	9.25	30.130
b805	0.856	1.986	0.59	0.146	33.1	226.712
b806	0.194	0.437	0.46	0.045	7.283	161.844
b808	0.172	0.388	0.18	0.049	6.466	131.959
b809	0.588	1.281	0.21	0.049	21.35	435.714
b889	0.767	1.779	0.3	0.036	29.65	823.611
b890	0.350	0.790	0.13	0.033	13.166	398.970
b891	0.072	0.162	0.35	0.044	2.7	61.364
b892	0.244	0.531	0.36	0.035	8.85	252.857
b894	0.345	0.800	0.36	0.034	13.333	392.147
b895	0.444	1.002	0.71	0.074	16.7	225.676
b897	0.339	0.765	0.11	0.032	12.75	398.438
b898	0.339	0.738	0.26	0.034	12.3	361.765
b899	0.261	0.605	0.35	0.037	10.083	272.514
b900	0.322	0.726	0.38	0.066	12.1	183.333
b902	0.117	0.264	0.17	0.035	4.401	125.743
b903	0.284	0.618	0.22	0.041	10.3	251.220
b904	0.361	0.837	0.37	0.047	13.95	296.809
b905	0.744	1.679	0.29	0.054	27.983	518.204
b906	0.672	1.516	0.18	0.069	25.267	366.188
b907	0.250	0.544	0.06	0.053	9.066	171.057
b909	0.450	1.144	0.17	0.096	17.4	181.250
b910	0.233	0.525	0.13	0.045	8.75	194.444
b911	0.050	0.112	0.27	0.052	1.866	35.885
b835	0.517	1.126	0.31	0.083	18.767	226.108
b871	0.405	0.939	0.88	0.108	15.65	144.907
b873	0.566	1.277	0.46	0.037	21.283	575.216

Rable 2 - Cont.

b874	0.278	0.627	0.73	0.033	10.45	197.170
b875	0.044	0.095	0.47	0.033	1.583	47.970
b876	0.316	0.733	1.26	0.371	12.216	32.927
b877	3.677	8.300	1.12	0.237	138.336	583.696
b878	0.222	0.501	0.52	0.06	8.35	139.167
b880	0.200	0.435	0.77	0.064	7.25	113.281
b882	0.350	0.812	0.48	0.043	13.533	314.721
b884	0.288	0.650	0.57	0.059	10.833	183.610
b885	0.311	0.702	0.6	0.055	11.7	212.727
b992	0.444	0.967	0.14	0.05	16.116	322.320
b940	0.372	0.863	0.42	0.05	14.383	287.660
b944	0.200	0.451	0.66	0.031	7.516	242.452
b948	0.378	0.853	0.25	0.061	14.216	233.049
b950	0.055	0.119	0.24	0.035	1.983	56.657
b952	0.738	1.712	0.24	0.046	28.533	620.283
b954	0.717	1.618	0.72	0.121	26.967	222.868
b956	0.327	0.738	0.19	0.052	12.3	236.538
b959	0.544	1.285	0.17	0.06	19.75	329.167
b962	0.384	0.890	0.42	0.088	14.833	168.557
b972	0.928	2.094	0.34	0.146	34.9	239.041
b973	0.294	0.663	0.13	0.053	11.05	208.491
b975	0.688	1.498	0.23	0.109	24.967	229.055
b998	0.295	0.684	0.08	0.034	11.4	335.294
b999	0.283	0.638	0.24	0.039	10.633	272.641
c008	0.083	0.187	0.12	0.039	3.116	79.897
c012	0.666	1.450	0.14	0.06	24.167	402.783
c032	0.161	0.373	0.69	0.052	6.216	119.538
c023	0.339	0.765	0.27	0.049	12.75	260.204
c024	0.161	0.363	1.06	0.033	6.05	183.333
c037	0.500	1.089	0.37	0.048	18.15	378.125
c040	0.284	0.658	0.77	0.031	10.966	353.742
c044	0.261	0.589	0.4	0.082	9.816	119.707
c048	0.405	0.914	0.46	0.093	15.233	163.796
c049	0.328	0.714	0.15	0.055	11.9	216.364
c050	0.422	0.979	0.48	0.076	16.316	214.684
c051	0.284	0.641	0.38	0.037	10.683	288.730
c052	0.172	0.388	0.28	0.044	6.466	146.955
c056	0.128	0.278	0.37	0.048	4.633	96.521
c057	0.444	1.030	0.26	0.04	17.167	429.175
c059	0.250	0.564	0.36	0.033	9.4	284.848

Table 2 - Cont.

c060	0.816	1.841	0.72	0.078	30.683	393.372
c065	0.250	0.544	0.23	0.05	9.066	181.320
c066	0.411	0.953	0.47	0.079	15.883	201.051
c070	0.061	0.137	0.42	0.05	2.283	45.660
c077	0.583	1.313	0.44	0.059	21.883	370.898
c014	1.450	3.159	0.44	0.106	52.651	496.708
c015	0.488	1.132	0.18	0.042	18.867	449.214
c069	0.233	0.525	0.2	0.026	8.75	336.538
c085	0.128	0.288	0.84	0.072	4.8	66.667
c087	0.222	0.483	0.77	0.058	8.05	138.793
c107	0.178	0.412	0.47	0.049	6.866	140.122
c108	0.666	0.223	0.74	0.121	3.716	30.711
c110	0.061	0.137	0.22	0.036	2.283	63.417
c088	0.155	0.337	0.61	0.039	5.616	144.000
c090	0.367	0.851	0.84	0.06	14.183	236.383
c095	0.100	0.225	0.62	0.036	3.75	104.167
c097	0.317	0.715	0.88	0.031	11.916	384.387
c099	0.400	0.871	0.26	0.107	14.516	135.664
c115	0.289	0.670	0.12	0.033	11.166	338.364
c120	0.388	0.875	0.41	0.04	14.597	364.925
c121	0.284	0.641	0.18	0.062	10.684	172.323
c131	0.278	0.645	0.18	0.044	10.75	244.318
c130	0.127	0.286	0.2	0.031	4.766	153.742
c132	0.850	1.918	0.23	0.066	31.967	484.348
c133	0.566	1.233	0.15	0.036	20.55	570.833
c134	0.406	0.941	0.38	0.086	15.683	182.360
c135	0.338	0.762	0.31	0.043	12.7	295.349
c136	0.328	0.740	0.29	0.052	12.333	237.173
c137	1.300	2.832	0.81	0.387	47.2	121.964
c139	0.406	0.941	0.61	0.098	15.683	160.031
c142	0.461	1.040	0.54	0.069	17.333	251.203
c143	0.372	0.839	0.55	0.138	13.983	101.326
c144	0.077	0.167	0.22	0.031	2.783	89.774
c148	0.206	0.477	0.41	0.057	7.95	139.474
c149	0.561	1.266	0.15	0.037	21.1	570.270
c151	0.283	0.638	0.42	0.05	10.633	212.660
c153	0.300	0.653	0.33	0.043	10.883	253.093
c155	0.272	0.631	0.15	0.082	10.516	128.244
c157	0.405	0.914	0.28	0.084	15.233	181.345
c159	0.139	0.313	0.32	0.032	5.216	163.000

Table 2 - Cont.

c162	0.061	0.132	0.31	0.049	2.2	44.898
c164	0.484	1.122	0.25	0.083	18.7	225.301
c170	0.950	2.144	0.28	0.086	35.734	415.512
c172	0.183	0.413	0.24	0.056	6.883	122.911
c174	0.295	0.642	0.24	0.076	10.7	140.789
c175	0.395	0.916	0.11	0.065	15.266	234.862
c176	0.250	0.564	0.01	0.03	9.4	313.333
c193	-0.050	-0.112	0.16	0.041	-1.866	-45.512
c195	1.217	2.651	0.59	0.031	44.184	1425.290
c203	0.150	0.348	0.77	0.102	5.8	56.863
c208	0.394	0.889	0.47	0.042	14.816	352.762
c209	0.127	0.286	0.09	0.037	4.766	128.811
c210	0.450	0.980	0.06	0.032	16.333	510.406
c213	0.239	0.554	0.54	0.072	9.233	128.236
c218	0.361	0.814	0.55	0.036	13.566	376.833
c221	0.483	1.090	0.42	0.083	18.167	218.880
c222	0.316	0.688	0.46	0.065	11.466	176.400
c224	0.100	0.232	0.38	0.034	3.866	113.706
c226	0.272	0.613	0.47	0.062	10.216	164.774
c229	0.187	0.422	0.27	0.058	7.033	121.259

Note: The symbols cpm and dpm stand for counts per minute and disintegrations per minute, respectively. The symbol mBq indicates milliBecquerel.